STUDIES ON A CHROMONE SCHIFF BASE AS AN OPTICAL ALUMINIUM ION CHEMOSENSOR

A

SYNOPSIS

Submitted in partial fulfillment of the

Requirements for the award of a degree

Of

Doctor of Philosophy

In the

Department of

CHEMISTRY

Submitted to

YBN UNIVERSITY

RAJAULATU, NAMKUM, RANCHI

JHARKHAND 834010 (INDIA)

~~**July, 2024**~~

June, 2022

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1. INTRODUCTION

Natural abundance of aluminum in the biosphere is ~8% of the total mineral components [1]. Although pure aluminium does not occur naturally in nature but the wide use of aluminium in human activities and acid rain results into the release of free aluminum ions (Al^{3+}) into the environment [2]. According to a report of World Health Organization (WHO), the average daily human intake of aluminium is about 3–10 mg [3]. Elevated level of concentrations of aluminium have been found to have adverse impacts on humans. It has been found that Al^{3+} ions exerted several neurotoxic effects in organisms such as Alzheimer's disease, Parkinson's disease, bone softening, chronic renal failure and smoking related diseases [4-6].

The close association between Al^{3+} and human health, the investigation of Al^{3+} detection attracts more and more attention in recent past. Several instrumental detection approaches were reported for the identification of Al^{3+} ions, including atomic absorption spectroscopy (AAS) [7], Voltammetry [7] and inductively-coupled plasma mass spectrometry (ICP-MS) [8]. But these techniques require relatively complicated sample

preparation and/or sample pre-treatment protocols. Moreover, these instruments are generally not portable and therefore cannot be applied for the in-field determination of Al^{3+} ions. In recent decades, the fluorescent sensing of different metal ions have been paid a great attention due to the advantages such as high sensitivity, selectivity [9], rapid response time and versatility [10-14]. Fluorescent sensors mainly involves Photoinduced Electron Transfer (PET) [15], Excited State Intramolecular Proton Transfer (ESIPT) [16], Fluorescence Resonance Energy Transfer (FRET) [17], C=N isomerization [18], excimer–exciplex formation [19], etc. as mechanistic approach for detection of metal ions.

The design and synthesis of molecular fluorescent sensors that are able to detect ions (cations/anions) is an area of immense interest. Once the analyte is recognized by the receptor, the fluorescence signal can be observed via changes in fluorescence intensity either by a fluorescence "turn on" or by a "turn off". The lack of spectroscopic characteristics and poor coordination ability of Al^{3+} are two main obstacles in the development of an Al^{3+} selective fluorescent probe [20].

In general, as Al^{3+} is a hard-acid, it has been found that Al^{3+} prefers to coordinate with hard-base donor sites like N and O atoms [21]. Moreover, Schiff-bases are well known as hard bases which can provide nitrogen-

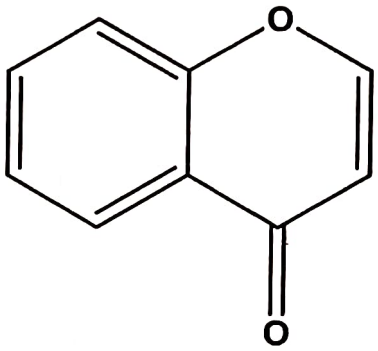
oxygen-rich coordination environments for better binding of Al^{3+}. As a consequence, a large number of Schiff-bases can be used as Al^{3+} probes. Chemosensors/optical receptors based on Schiff bases have demonstrated excellent performance for the determination of various metal ions owing to their facile and inexpensive synthesis, and their ability to coordinate with a variety of metal ions and stabilize them in a different of oxidation states.

Schiff bases are chemical compounds that have a (>C=N-) group was first synthesized by Hugo Schiff in 1864. It is also called the azomethine (–CH=N-) group, which shows good bonding affinity with metal ions. Schiff bases are formed by the simple condensation reaction of a carbonyl compound with a primary amine. Besides importance of Schiff bases in the field of medicine, industry, agriculture, catalysis, analytical chemistry, it is now also find application in chemical and optical sensors due to their accurate, efficient sensing properties and ease of synthesis.

Several fluorescent probes based on naphthalene, tetrazole, 8-hydroxyquinoline, coumarin, BODIPY etc. have been designed and synthesized for the determination of Al^{3+} but many of them have severe drawback i.e. use of obnoxious solvent [22], low detection limits [23] and low binding constants [24]. We started working on chromone framework because of the preeminent photophysical properties, less toxicity, high

quantum yield and large absorption coefficient, Chromone skeleton is an ideal model for constructing fluorescent probes.

CHROMONE



4*H*-chromen-4-one

The chromone and related compounds are widespread in the plant kingdom from algae to conifers. Chromones have found to be active in a number of plant cycles, including growth regulation, indole acetic acid oxidation and dormancy inhibition as well as exhibiting cytokinin-type behaviour and stimulating. Chromone derivatives are abundant in nature and exhibit a wide range of pharmacological activity [25-27], like anti-bacterial, anti-fungal, anti-cancer, anti-oxidant, anti-HIV, anti-ulcers], immune stimulators, biocidal, wound healing , anti-inflammatory and immune-stimulatory. Many chromone derivatives are also photoactive and can be used easily in various photoinduced reactions affording diverse heterocyclic

compounds. Chromone derivatives are also active at benzodiazepine receptors and on lipoxygenase and cyclooxygenase.

2. *LITERATURE REVIEW*

A number of organic molecular probes have been reported for Al^{3+} ion monitoring in the literature. However, the rapid industrialization which produces new ionic and metallic pollutants in the ecosystem may affect both plant and human life. Thus, new chemosensors having high sensitivity and selectivity towards a particular ion is desired.

Some of the chemosensors reported in literature in recent past are summarized as below;

Kumar and Upadhyay e al. have reported some of promising colorimetric and fluorescent receptors for selective and sensitive detection Al^{3+} ion. The backbone of these receptors are based upon various organic moieties such as uracil [28], pyrimidine [29], salicylimine [30], naphthalene [31] etc.

Goswami et al. (2013) have reported a Schiff base fluorescent isophthaloyl salicylaldehyde hydrazone [32] which selectively detected Al^{3+} and PPi with a strong fluorescence enhancement in aqueous solution via inhibition of CH=N isomerisation and ICT processes through CHEF process.

Samanta et al. (2014) have explained [33] an aggregation induced emission (AIE) active probe for Al (III) sensing. The probe-Al^{3+} ensemble have been captured through a systematic fluorescence TURN-OFF response of the highly emissive ensemble.

Maity and Govindaraju (2010) have reported a fluorescent probe [34], pyrrolidine constrained bipyridyl–dansyl (ionophore–fluorophore) conjugate having a triazole linker. The fluoroionophore served as a ratiometric and colorimetric sensor for Al^{3+} in acetonitrile.

Patil et al. (2014) have reported a fluorescent probe [35] based on benzothiazole to monitor intracellular Al^{3+} levels in living cells through CHEQ mechanism.

Liu et al. (2017) have reported an acylhydrazone derivative 4-chloro-N′-(pyridin-2-ylmethylene) benzo- hydrazide (CPBH) [36] to be a fluorescence probe for Al^{3+} due to a reduced intramolecular charge transfer and chelation enhanced fluorescence mechanism. The limit of detection for Al^{3+} is 0.2 μM (5.4 ppb), and the linear range is from 2 to 15 μM.

Literature survey reveals that compared to other transition metal ions, detection of Al^{3+} ion has always been troublesome to due to its poor coordination ability, strong hydration ability and the lack of spectroscopic characteristics. Most of the reported Al^{3+} fluorescent probes suffer from

some limits, such as non-responsive in aqueous medium [Liu et al, (2016)] [37], poor selectivity or sensitivity, weak binding ability, quenched interference caused by Cu^{2+} and Fe^{3+}, their tedious synthetic methods, high detection limit [Ren et al (2016)] [38], without intracellular studies [Jiang et al. (2011) [39], and Velmurugan et al. (2015) [40].

3. *OBJECTIVES, SCOPE AND LIMITATIONS OF THE PRESENT RESEARCH*

3.1. Objectives- The objectives of the present proposal are two folds:

- To synthesize and characterize some new roptical eceptors based on chromone derivatives.
- To evaluate the above newly synthesized receptors for the sensing of Aluminium ions

3.2. Scope and Limitations of the Present Research

- Fluorescent probes have been widely applied for inorganic ions and neutral molecules sensing in various fields such as physiological, environmental and pharmaceutical sciences. Regardless of the progress in this field, certain problems and issues still have to overcome.
- Although fluorescent probes based on chromone moiety had cover up many applications in various fields yet there is need of new optical chemosensors in biological and environmental analysis. This is because

of the rapid industrialization which produces new ionic and metallic pollutants in the ecosystem, hence affecting both plant and human life.

- The present study involves synthesis, characterization and evaluation of chromone derivatives for detection of ions. The ions play crucial roles in the bio-chemistry of the life processes as well as in environment hence their qualitative and quantitative measurement is worth full. The ions which have been targeted are *s* and *p* block metal ions as well as transition metal ions.
- The lack of spectroscopic response and poor coordination ability of Al^{3+} are two main obstacles in the development of an Al^{3+} selective fluorescent probe.
- However, the sensors proposed to be synthesized in this proposal possess polar –NH– group at the same time they also possess N and O donor atoms as well as –CH=N- functionality which is able to have interaction with cationic species.
- At the same time the receptor possess *chromone and pyridine moiety* as the signalling and binding unit for the evaluation of sensing ability of the receptors with suitable cations.
- The receptors planned under this proposal are fluorescent one i.e., able to provide optical output with suitable analyte.

- To overcome the difficulties and challenges in this field of research, there is a need of new improved chemosensors which are designed not only for trace level detection but also to estimate the analyte with great accuracy.

4. *RESEARCH METHODOLOGY*

The entire plan of work for the present research proposal may be subdivided under following headings.

- **Synthesis of receptors:** Chromone based optical receptors were synthesized through simple Schiff base condensation reaction via reaction between respective amine and aldehyde.
- **Characterization of newly synthesized receptors:** For the characterization purposes Infrared (IR), UV-visible, Nuclear magnetic resonance (NMR) spectroscopic methods will be used besides mass determination. Sincere efforts will be done to develop crystals of suitable shape and size of the above receptors for their X-ray diffraction studies.
- **Evaluation of Receptors for the ion sensing:** The receptors planned in this proposal possess –NH– functionality along with N and O donor atoms hence they will be able to develop the interaction with the cations. UV-visible and ^{1}H NMR titrations between standard solutions of receptor and analyte will be performed in order to have an idea about the quantitative

aspect of binding of receptor with analyte. The mole ratio and Job's continuous variation method[37] will be used to derive ratio between receptor and analyte at the point of recognition. Furthermore, calculations of binding constants through UV-visible and ^{1}H NMR titration data will provide an idea about the suitability of a particular receptor for a particular analyte.

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